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(56) Documents cited

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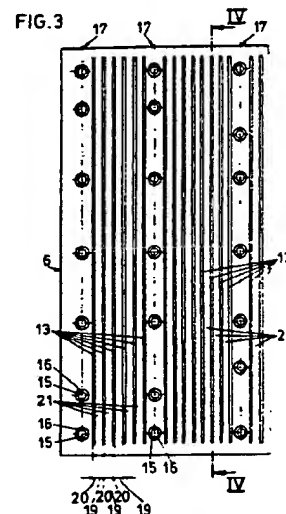
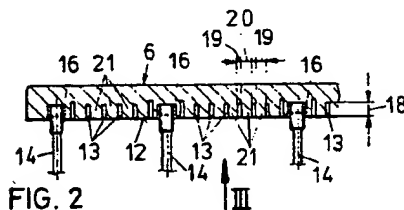
(58) Field of search

UK CL (Edition J) B3F FHD FHK FMS

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(54) **A continuous casting mould cooling arrangement**

(57) In a continuous casting mould, the mould side walls are each formed by a supporting wall and an internal copper plate fastened thereto for contact with the metal melt. On the face of the internal plate (6) facing the supporting wall, parallel coolant channels are provided, which comprise slits (13) open towards the supporting wall. For each slit (13), the width (19) is smaller, and depth (18) is larger, than the width (20) of the ribs (21) located between the slits. The rib width (20) is 13mm (max) and the flow speed of the coolant is adjusted such that the heat transmission coefficient between the internal plate and the coolant is between 20 and 70 kW/m²K, preferably between 25 and 50 kW/m²K, such that the heat flow density for the internal plate is larger than the heat flow density for a smooth internal plate having no ribs.



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FIG. 1

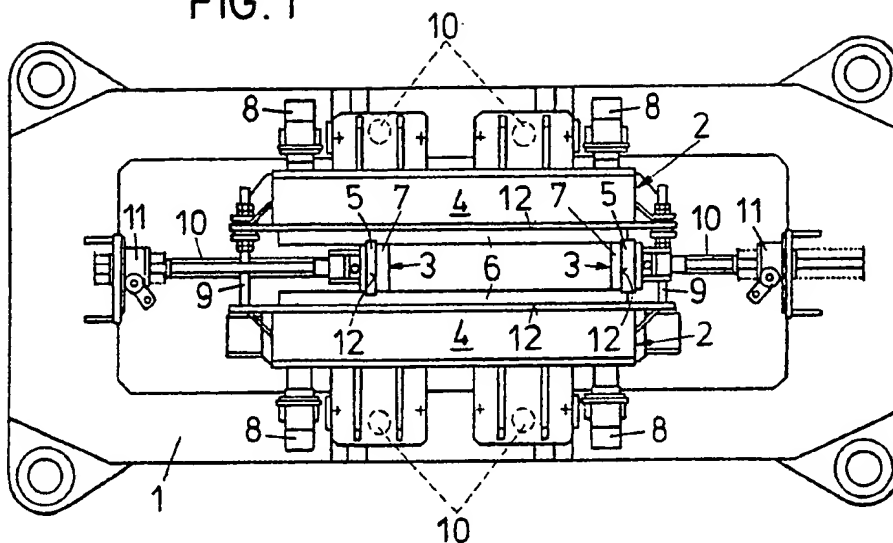


FIG. 5

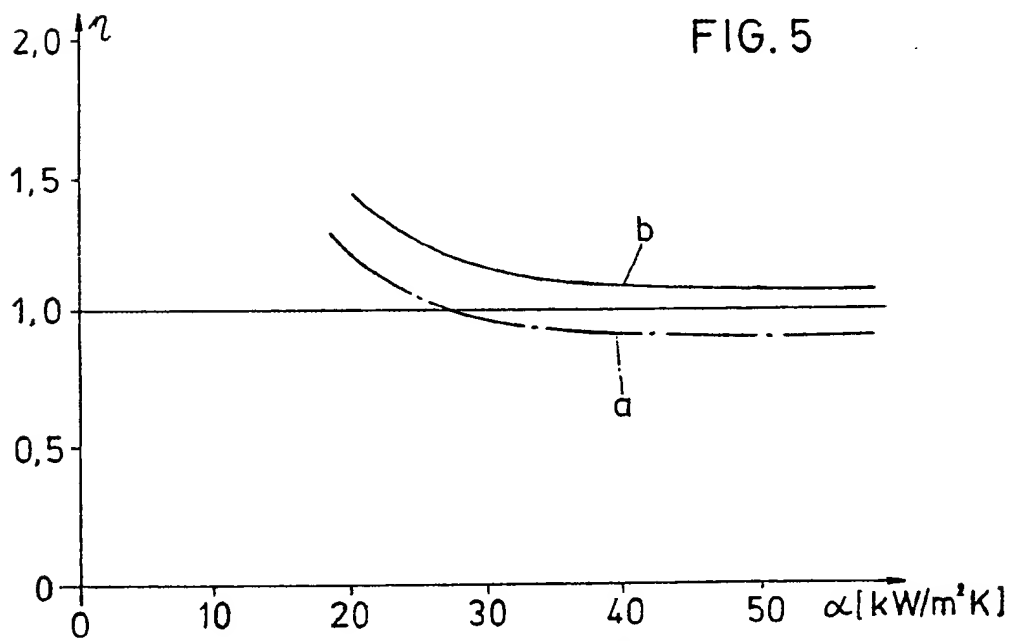


FIG. 6

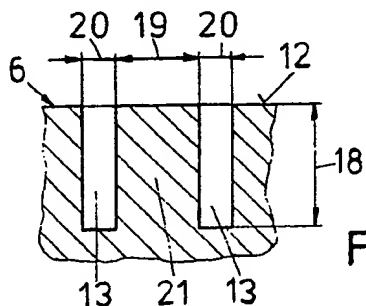
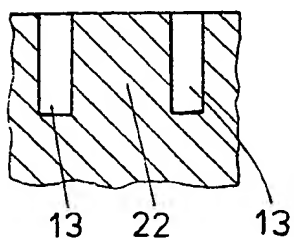


FIG. 7

FIG. 3

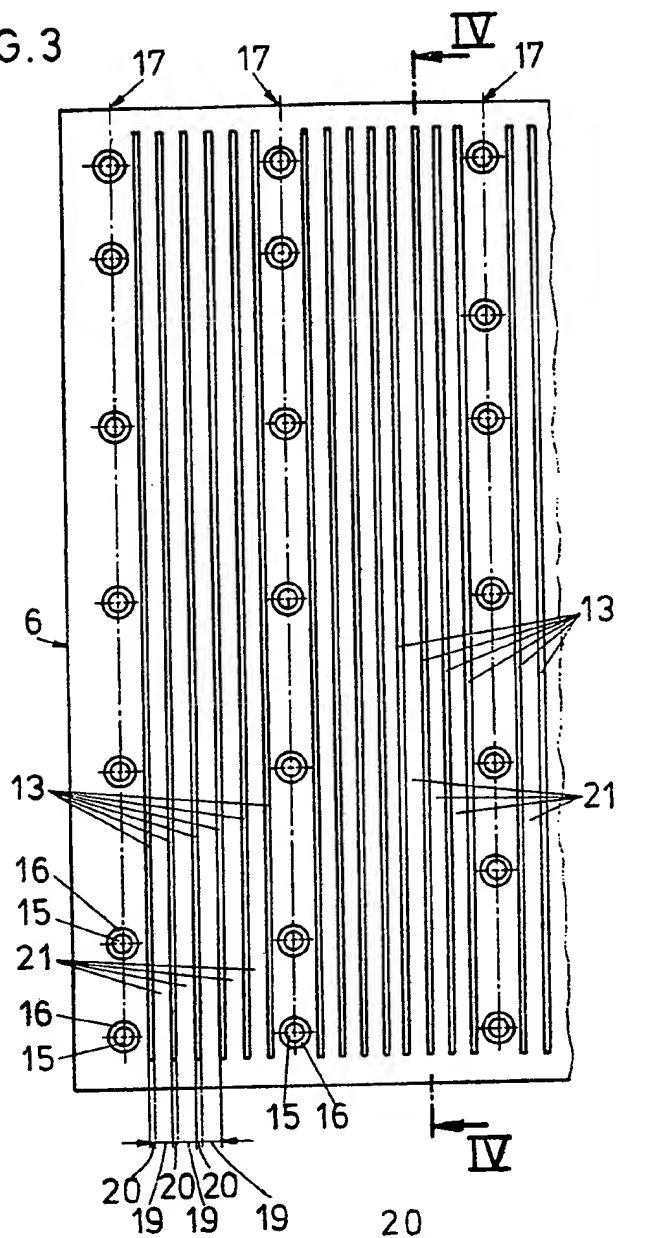


FIG. 4

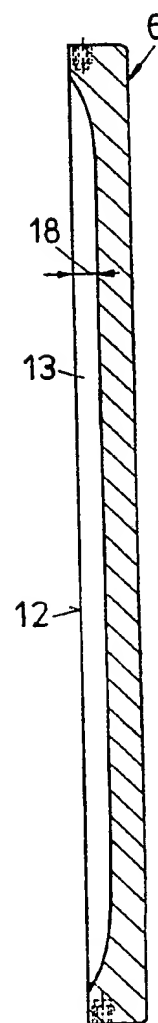
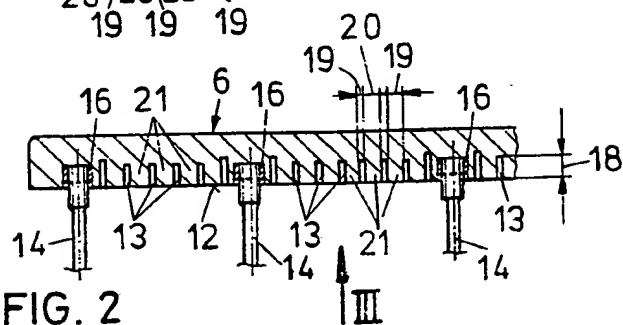


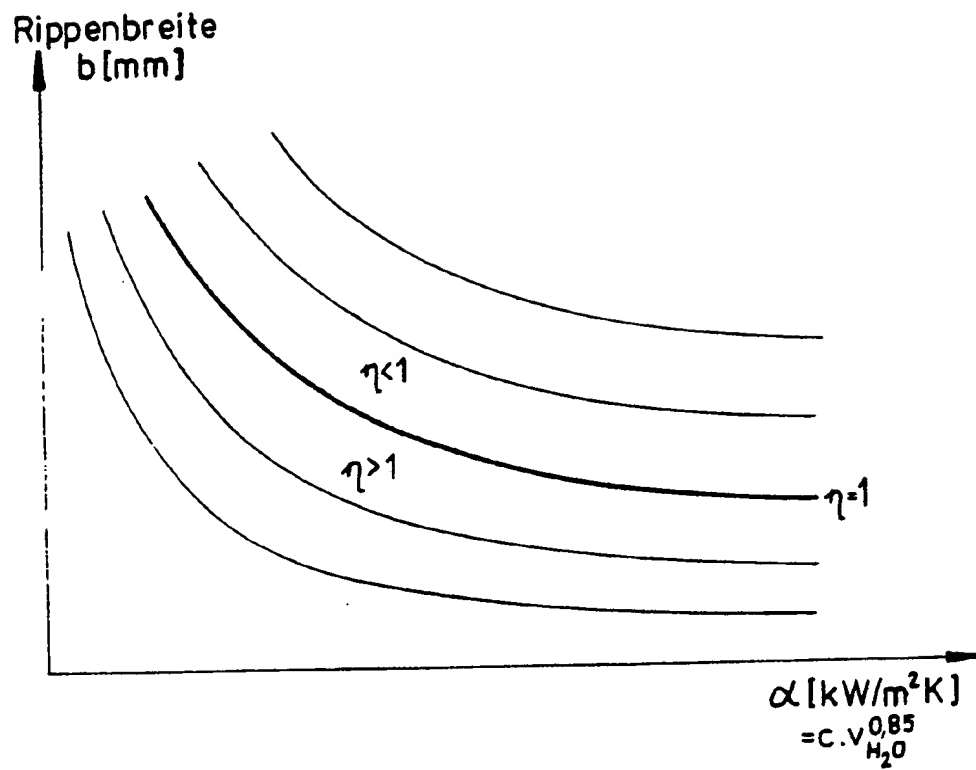
FIG. 2



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FIG. 8



IMPROVEMENTS IN OR RELATING TO A CONTINUOUS CASTING MOLD
ARRANGEMENT

The invention relates to a continuous casting mold, in particular a plate mold for continuously casting billets and blooms or slabs of steel, wherein the mold side walls are each formed by a supporting wall and an internal plate fastened thereto and getting into contact with the metal melt, and wherein on the side of the internal plate facing the supporting wall parallelly arranged coolant channels are provided, which are designed as slits open towards the supporting wall and whose width is smaller and whose depth is larger, than the width of the ribs located between the slits.

Continuous casting molds of this type (U.S. patents Nos. 3,866,664 and 3,763,920) are used to cast steel strands having slab or billet or bloom cross sections. In order to keep the temperature of the internal plates, which, as a rule, are made of copper or of a copper alloy, low even at high casting speeds, much emphasis has been laid on the intensive and uniform cooling of the internal plates.

With known continuous casting molds, the ribs provided between the coolant channels serve to keep the amount of coolant required per time unit low and to attain a high flow speed of the coolant. Moreover, it is possible, on account of the ribs, to keep the machining volume low at the manufacture of the internal plates.

From Nippon Kokan Technical Report, No. 48 (1987) it is known to provide 5 mm wide and 15 mm deep slits as

coolant channels, at a distance of 20 mm. However, this embodiment allows for but little effective cooling so that one is forced to adjust a relatively high coolant speed in order to ensure an acceptable temperature of the internal plates, which, in turn, causes the efficiency to decrease.

The invention aims at avoiding this disadvantage and has as its object to provide a continuous casting mold of the initially defined kind, with which particularly effective cooling by means of a slight specific amount of coolant only and at not too high a coolant speed is feasible. In particular, only little volume is to be machined at the manufacture of the internal plates.

In accordance with the invention, this object is achieved in that the width of the cooling ribs is smaller than, or equal to, 13 mm and that the flow speed of the coolant is adjusted such that the heat transmission coefficient α between the internal plate and the coolant is between 20 and 70 kW/m²K, preferably between 25 and 50 kW/m²K, such that the heat flow density for the internal plate is larger than the heat flow density for a smooth internal plate having no ribs.

The invention is based on the finding that the ribs provided between the coolant channels are able to function as cooling ribs only if the ratio of the depth of a slit to the width of a cooling rib is larger than 1 and, in addition to this condition, if the heat

transmission coefficient alpha lies within the margins indicated above. Hence results a coolant speed that is low as compared to the prior art, and which is at a relation to the heat transmission coefficient alpha of
5 $\alpha = c \cdot v_{H_2O}^{0.85}$ such that an efficient heat emission is ensured without overheating the coolant. If the ratio of the depth of a slit to the width of a cooling rib is smaller than 1, the ribs will have an adverse influence on the cooling effect, i.e., cooling will be impaired by
10 the ribs; in that case, a smooth-wall design of the rear side of the internal plates omitting the ribs would be more effective.

Investigations have proved that the heat flow density (the amount of heat carried away per time unit
15 and area unit by a coolant flowing at a predetermined coolant speed) is larger for a smooth plate than for a plate of equal thickness to which prior art ribs have been molded. The ratio of the heat flow density of a plate equipped with ribs to the heat flow density of a
20 smooth plate will become larger than 1 only if the ribs assume the function of "cooling ribs", i.e. if they intensify the cooling effect; and this the case only if specific ratios of geometric dimensions and a specific magnitude of the heat transmission coefficient alpha are
25 observed. What is decisive in the first place is the maximum width of a rib.

Preferably, the width of a slit is between 3 and 7

mm and the ratio of the slit width to the rib width is one to two at the most. The slit geometry is important for the cooling to function, the more so as a slit must not be dimensioned too narrow, since impurities might deposit there and the fabrication of the slit would no longer be possible, because a particularly thin milling cutter were required. On the other hand, the slits must not be dimensioned too wide, since too much volume would have to be machined at the manufacture of the slits.

10 The invention will now be explained in more detail by way of two embodiments with reference to the accompanying drawings, wherein:

Fig. 1 is a top view onto the mold in a schematic illustration;

15 Fig. 2 represents a cross sectional view through an internal plate on an enlarged scale;

Fig. 3 is a view of the internal plate in the direction of the arrow III of Fig. 2;

Fig. 4 illustrates a section along line IV-IV of Fig. 3;

20 Fig. 5 is a diagrammatic view of the dependency of the cooling efficiency on the heat transmission coefficient for the various internal plates shown in Figs. 6 and 7,

Fig. 6 being an embodiment according to the prior art, and

25 Fig. 7 illustrating an embodiment according to the invention;

Fig. 8 shows the dependency of the efficiency on the rib width and on the heat transmission coefficient.

In a frame-shaped water box 1 of a plate mold used to cast steel strands having slab cross section, broad side walls 2 and end side walls 3 are arranged. The broad side walls 2 and the end side walls 3 each are formed by a supporting wall 4, 5 to which an internal plate 6, 7 is fastened, which latter gets into contact with the metal melt. For continuous casting, the internal plates 6, 7 for continuous casting, as a rule, are made of copper or a copper alloy.

The broad side walls 2 are displaceable towards and away from each other by adjustment drives 8 mounted to the water box 1, and may be fixed in various positions relative to each other by a fixing means 9 such that clamping of the end side walls 3 between the broad side walls or providing a gap of constant size between the broad side walls 2 and the end side walls 3 is feasible.

Both the broad side walls 2 and the end side walls 3 are connected to the water box 1 by means of cooling water supplies 10. Adjustment drives 11, which for instance, are comprised of threaded spindles and are connected to the upper or lower rim portion of each end side wall 3 serve to displace, and to adjust the inclination of, each end side wall 3.

The internal plates 6, 7 of the end and broad side walls 2, 3, on their rear sides 12, i.e., on the sides

abutting on the respective supporting walls 4, 5, are provided with parallelly arranged coolant channels designed as slits 13 open towards the supporting walls 4, 5. The side walls delimiting the slits preferably are parallel to each other and preferably are oriented perpendicular to the plane of the internal plate. In order to prevent the internal plates 6, 7 from getting warped, they are rigidly fastened to the supporting walls 4, 5 by means of numerous clamping bolts 14. The bores 15 that serve to screw in the clamping bolts 14 and which, suitably, are formed by intermediate sleeves 16 inserted into the internal plates 6, 7, are arranged in parallel rows 17 as is apparent particularly from Fig. 3. The slits 13 conducting the coolant are provided between these rows 17 extending in the height direction of the mold.

The slits 13 are arranged in a manner that the ratio of the depth 18 of a slit 13 to the distance of two neighboring slits 13, i.e., the width 19 of the intermediately arranged ribs 21, is larger than 1 in the area regions between the hole rows 17. The slits 13 have a width 20 of 5 mm (preferably their width amounts to between 3 and 7 mm), the intermediately arranged ribs 21 are 11 mm and, in the end region adjacent one end of the internal plate 6 between two hole rows 17, are 12 mm wide. Their depth 18 is to be seen from Figs. 2 and 4; it amounts to 18 mm. The overall thickness 22 of the

internal plates 6, 7 is 40 mm. The internal plates 6, 7 may be refinished by about 11 mm on the sides that get into contact with the metal melt.

In the embodiment illustrated, the bottom of the
5 slits 13 is plane, yet it could also be semi-circular.

The slits 13 are passed by a coolant, the ribs 21 located between the slits 13 functioning as cooling ribs. This is explained in more detail with reference to Fig. 5, which represents a diagram, in which the efficiency
10 η is plotted on the ordinate and the heat transmission coefficient α is plotted on the abscissa. The efficiency η expresses the ratio of the heat flow density of a wall provided with slit-shaped coolant channels to the heat flow density of a smooth wall
15 resulting when the ribs 21 formed by the slits 13 have been omitted.

For all η s smaller than 1, the ribs 21 do not function as cooling ribs, but there will occur a poorer cooling effect than with the smooth comparative wall,
20 i.e., the ribs interfere with the heat transmission. If η is larger than 1, cooling will be improved by the ribs 21 as compared to a smooth wall, which means that the ribs 21 function as cooling ribs on account of the cooling effect intensified by them.

25 In Fig. 5, the range of the heat transmission coefficient between 20 and 50 kW/m²K, in particular, is illustrated in respect of two different embodiments of

slits and cooling ribs. The dot-and-dash line a indicates the dependency of the efficiency η on the heat transmission coefficient α between 20 and 50 $\text{KW/m}^2\text{K}$ in respect of the rib 22 illustrated in Fig. 6 (with
5 which the ratio depth - 15 mm - of the slit 13 to width - 15 mm - of a rib 22 is 1). η is more than one only from a value α of less than 24. The rib 22 illustrated in Fig. 6, therefore, is effective as a cooling rib with very small heat transmission coefficients α and,
10 thus, with low coolant speeds only. Yet, such a coolant speed would bring about only insufficient cooling of the internal plate and, therefore, must not be adjusted in practice.

The basic relationship between the width of a rib,
15 the heat transmission coefficient α and, thus, the coolant speed $v_{\text{H}_2\text{O}}$ (which results from the relation $\alpha = \text{constant} \cdot v_{\text{H}_2\text{O}}^{0.85}$) and the efficiency η is illustrated in Fig. 8.

It is apparent from Fig. 8 that, with a given rib
20 width, the flow speed $v_{\text{H}_2\text{O}}$ of the coolant constitutes an important factor as to whether the rib does function as a "cooling rib" or not in a sense that the higher the coolant speed - which causes an increase in the amount of heat carried away, though - the poorer the efficiency
25 η .

By way of the following Table, this fact is explained with reference to the embodiments illustrated

in Figs. 6 and 7. In line I, the conventional plate construction illustrated in Fig. 6 is demonstrated, and in line II the plate construction according to Fig. 7 is demonstrated. In the Table, the efficiency η both for a low and a high coolant speed v_{H_2O} , the value α and the value $\alpha_{eff} = \alpha \times \eta$ are each indicated. It is apparent that, with the construction according to the invention, a lower coolant speed results with the same value for α_{eff} of 50,000.

10

		η	α	α_{eff}	v_{H_2O}	Δp [bar]
	I (Fig. 6)	1.244	20,000	24,887	3.32	
15		0.929	53,845	50,000	10.63	0.89
	II (Fig. 7)	1.426	20,000	28,520	3.34	
		1.083	46,150	50,000	8.92	0.62

20 From this Table it can be seen that, in order to adjust equally low temperatures at the internal plates illustrated in Fig. 6 and Fig. 7, a lower coolant speed v_{H_2O} and, thus, a lower specific coolant amount, a slighter pressure loss Δp and a lower pump
25 performance are necessary with the embodiment according to the invention (Fig. 7).

The curve b entered in a solid line represents the efficiency η for different heat transmission coefficients α resulting at a cooling rib 21 according to Fig. 7. It is apparent that, with all the heat transmission numbers under consideration, this curve lies above the straight line $\eta = 1$ so that the cooling rib 21 illustrated in Fig. 7 acts as a cooling rib in any event, i.e., even with totally different coolant speeds. With the cooling rib illustrated in Fig. 7, the ratio of depth 18 of the slit 13 to width 19 of the rib 21 lies at 1.5.

It has proved that, with an internal plate 6, 7 provided with slits 13, the cooling effect can be increased relative to a smooth-wall internal plate in respect of the usual coolant amounts and coolant speeds, if the ratio of the height of the ribs and the depth 18 of the slits to the width 19 of the ribs 21 is larger than 1. The width 20 of the slits 13 usually is 5 mm, depending on manufacturing engineering conditions, i.e., on the power of the milling cutters that serve to make the slits 13, which latter may not be made too thin and may not exceed a certain width in order to keep the machining volume as low as possible.

CLAIMS:

1 1. In a continuous casting mold arrangement, such as
2 a plate mold for continuously casting billets and blooms
3 or slabs of steel, of the type including mold side wall
4 means each composed of a supporting wall and an internal
5 plate fastened to said supporting wall and adapted to get
6 into contact with metal melt, parallelly arranged coolant
7 channels provided on said internal plate on its side
8 facing said supporting wall, said coolant channels being
9 designed as slits open towards said supporting wall and
10 adapted to let a coolant pass therethrough, and ribs
11 located between said slits, each of said ribs having a
12 rib width and each of said slits having a slit width
13 that is smaller and a slit depth that is larger, than
14 said rib width, the improvement wherein said side rib
15 width is at most 13 mm and said coolant passes through
16 said slits at a flow speed adjusted in a manner that a
17 heat transmission coefficient α prevails between said
18 internal plate and said coolant, that amounts to between
19 20 and 70 kW/m²K such that said internal plate has a
20 heat flow density that is larger than the heat flow
21 density of a smooth internal plate having no ribs.

1 2. A continuous casting mold arrangement as set forth
2 in claim 1, wherein said heat transmission coefficient
3 amounts to between 25 and 50 kW/m²K.

1 3. A continuous casting mold as set forth in claim 1,
2 wherein said slit width is between 3 and 7 mm and the
3 ratio of said slit width to said rib width is 1 to 2 at
4 most.

1 4. A continuous casting mold substantially as herein-
2 before described with reference to the accompanying
3 drawings.